

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
20 June 2002 (20.06.2002)

PCT

(10) International Publication Number  
**WO 02/48291 A1**

(51) International Patent Classification<sup>7</sup>: **C10G 67/04,**  
73/08, 73/38

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(21) International Application Number: **PCT/US01/43530**

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(22) International Filing Date:  
16 November 2001 (16.11.2001)

(25) Filing Language:

English

(81) Designated States (*national*): AE, AG, AL, AM, AT, AU,  
AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU,  
CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH,  
GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC,  
LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW,  
MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK,  
SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

(26) Publication Language:

English

(30) Priority Data:

09/737,008 14 December 2000 (14.12.2000) US  
09/892,384 26 June 2001 (26.06.2001) US

(84) Designated States (*regional*): ARIPO patent (GH, GM,  
KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW),  
Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM),  
European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR,  
GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent  
(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR,  
NE, SN, TD, TG).

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**Published:**

— with international search report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



**A1**

(54) Title: RAFFINATE HYDROCONVERSION PROCESS

(57) Abstract: A process for producing a high VI/low volatility lubricating oil basestock and a lubricating oil basestock prepared by said process. The process comprises subjecting the raffinate from a solvent extraction step to a two step, single stage hydroconversion process wherein the first step involves severe hydroconversion of the raffinate followed by a cold hydrofinishing step.

**WO 02/48291**

## RAFFINATE HYDROCONVERSION PROCESS

### FIELD OF THE INVENTION

[0001] This invention relates to lubricating oil basestocks and to a process  
5 for preparing lubricating oil basestocks having high viscosity indices and low  
volatilities.

### BACKGROUND OF THE INVENTION

[0002] It is well known to produce lubricating oil basestocks by solvent refining. In the conventional process, crude oils are fractionated under atmospheric pressure to produce atmospheric resids which are further fractionated under vacuum. Select distillate fractions are then optionally deasphalting and solvent extracted to produce a paraffin rich raffinate and an aromatics rich extract. The raffinate is then dewaxed to produce a dewaxed oil which is usually hydrofinished to improve stability and remove color bodies.

15 [0003] Solvent refining is a process which selectively isolates components of crude oils having desirable properties for lubricant basestocks. Thus the crude oils used for solvent refining are restricted to those which are highly paraffinic in nature as aromatics tend to have lower viscosity indices (VI), and are therefore less desirable in lubricating oil basestocks. Also, certain types of aromatic compounds  
20 can result in unfavorable toxicity characteristics. Solvent refining can produce lubricating oil basestocks have a VI of about 95 in good yields.

[0004] Today more severe operating conditions for automobile engines have resulted in demands for basestocks with lower volatilities (while retaining low viscosities) and lower pour points. These improvements can only be achieved with  
25 basestocks of more isoparaffinic character, i.e., those with VI's of 105 or greater. Solvent refining alone cannot economically produce basestocks having a VI of 105 with typical crudes. Two alternative approaches have been developed to produce

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- high quality lubricating oil basestocks; (1) wax isomerization and (2) hydrocracking. Both of the methods involve high capital investments and suffer from yield debits. Moreover, hydrocracking eliminates some of the solvency properties of basestocks produced by traditional solvent refining techniques. Also, 5 the typically low quality feedstocks used in hydrocracking, and the consequent severe conditions required to achieve the desired viscometric and volatility properties can result in the formation of undesirable (toxic) species. These species are formed in sufficient concentration that a further processing step such as extraction is needed to achieve a non-toxic base stock.
- 10 [0005] An article by S. Bull and A. Marmin entitled "Lube Oil Manufacture by Severe Hydrotreatment", Proceedings of the Tenth World Petroleum Congress, Volume 4, Developments in Lubrication; PD 19(2), pages 221-228, describes a process wherein the extraction unit in solvent refining is replaced by a hydrotreater.
- 15 [0006] U.S. Patent 3,691,067 describes a process for producing a medium and high VI oil by hydrotreating a narrow cut lube feedstock. The hydrotreating step involves a single hydrotreating zone. U.S. Patent 3,732,154 discloses hydrofinishing the extract or raffinate from a solvent extraction process. The feed to the hydrofinishing step is derived from a highly aromatic source such as a naphthenic distillate. U.S. patent 4,627,908 relates to a process for improving the 20 bulk oxidation stability and storage stability of lube oil basestocks derived from hydrocracked bright stock. The process involves hydrodenitration of a hydrocracked bright stock followed by hydrofinishing.
- 25 [0007] It would be desirable to supplement the conventional solvent refining process so as to produce high VI, low volatility oils which have excellent toxicity, oxidative and thermal stability, solvency, fuel economy and cold start properties

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without incurring any significant yield debit which process requires much lower investment costs than competing technologies such as hydrocracking.

### SUMMARY OF THE INVENTION

[0008] This invention relates to a process for producing a lubricating oil

5 basestock which comprises:

(a) conducting a lubricating oil feedstock to a solvent extraction zone and under-extracting the feedstock to form an under-extracted raffinate wherein the extraction zone solvent contains water added in the amount from about 1 to about 10 vol.%, based on extraction solvent, such that the extraction solvent  
10 contains from 3 to 10 vol.% water;

(b) stripping the under-extracted raffinate of solvent to produce an under-extracted raffinate feed having a dewaxed oil viscosity index from about 75 to about 105;

(c) passing the raffinate feed to a first hydroconversion zone and  
15 processing the raffinate feed in the presence of a non-acidic catalyst at a temperature of from about 320 to about 420°C, a hydrogen partial pressure of from about 800 to about 2500 psig (5.6 to 17.3 mPa), space velocity of about 0.2 to about 5.0 LHSV, and a hydrogen to feed ratio of from about 500 to about 5000 Scf/B (89 to 890 m<sup>3</sup>/m<sup>3</sup>) to produce a first hydroconverted raffinate; and

20 (d) passing the first hydroconverted raffinate to a second reaction zone and conducting cold hydrofinishing of the first hydroconverted raffinate in the presence of a hydrofinishing catalyst at a temperature of from about 200 to about 360°C, a hydrogen partial pressure of from about 800 to about 2500 psig (5.6 to

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17.3 mPa), a space velocity of from about 1 to about 10 LHSV, and a hydrogen to feed ratio of from about 500 to about 5000 Scf/B (89 to 890 m<sup>3</sup>/m<sup>3</sup>) to produce a hydrofinished raffinate.

[0009] The basestocks produced by the process according to the invention  
5 have excellent low volatility properties for a given viscosity thereby meeting future industry engine oil standards while achieving good solvency, cold start, fuel economy, oxidation stability and thermal stability properties. In addition, toxicity tests show that the basestock has excellent toxicological properties as measured by tests such as the FDA(c) test.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

[0010] Figure 1 is a plot of NOACK volatility vs. viscosity index for a 100N basestock.

[0011] Figure 2 is a simplified schematic flow diagram of the raffinate hydroconversion process.

15 [0012] Figure 3 is a plot of the thermal diffusion separation vs. viscosity index.

[0013] Figure 4 is a graph showing raffinate feed quality as a function of dewaxed oil yield and basestock viscosity.

20 [0014] Figure 5 is a graph showing viscosity vs. Noack volatility for different basestocks.

[0015] Figure 6 is a graph showing Noack volatility vs. basestock type.

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[0016] Figure 7 is a graph showing percent viscosity increase and oil consumption as a function of basestock type.

#### DETAILED DESCRIPTION OF THE INVENTION

- [0017] The solvent refining of select crude oils to produce lubricating oil basestocks typically involves atmospheric distillation, vacuum distillation, extraction, dewaxing and hydrofinishing. Because basestocks having a high isoparaffin content are characterized by having good viscosity index (VI) properties and suitable low temperature properties, the crude oils used in the solvent refining process are typically paraffinic crudes. One method of classifying lubricating oil basestocks is that used by the American Petroleum Institute (API). API Group II basestocks have a saturates content of 90 wt.% or greater, a sulfur content of not more than 0.03 wt.% and a viscosity index (VI) greater than 80 but less than 120. API Group III basestocks are the same as Group II basestocks except that the VI is greater than or equal to 120.
- [0018] Generally, the high boiling petroleum fractions from atmospheric distillation are sent to a vacuum distillation unit, and the distillation fractions from this unit are solvent extracted. The residue from vacuum distillation which may be deasphalting is sent to other processing.
- [0019] The solvent extraction process selectively dissolves the aromatic components in an extract phase while leaving the more paraffinic components in a raffinate phase. Naphthenes are distributed between the extract and raffinate phases. Typical solvents for solvent extraction include phenol, furfural and N-methyl pyrrolidone. By controlling the solvent to oil ratio, extraction temperature

and method of contacting distillate to be extracted with solvent, one can control the degree of separation between the extract and raffinate phases.

[0020] In recent years, solvent extraction has been replaced by hydrocracking as a means for producing high VI basestocks in some refineries. The hydrocracking process utilizes low quality feeds such as feed distillate from the vacuum distillation unit or other refinery streams such as vacuum gas oils and coker gas oils. The catalysts used in hydrocracking are typically sulfides of Ni, Mo, Co and W on an acidic support such as silica/alumina or alumina containing an acidic promoter such as fluorine. Some hydrocracking catalysts also contain highly acidic zeolites. The hydrocracking process may involve hetero-atom removal, aromatic ring saturation, dealkylation of aromatics rings, ring opening, straight chain and side-chain cracking, and wax isomerization depending on operating conditions. In view of these reactions, separation of the aromatics rich phase that occurs in solvent extraction is an unnecessary step since hydrocracking can reduce aromatics content to very low levels.

[0021] By way of contrast, the process of the present invention utilizes a two step hydroconversion of the raffinate from the solvent extraction unit under conditions which minimizes hydrocracking and hydroisomerization while maintaining a residual aromatics content consistent with the objective of high saturates.

[0022] The distillate feeds to the extraction zone are from a vacuum or atmospheric distillation unit, preferably from a vacuum distillation unit and may be of poor quality. The feeds may contain nitrogen and sulfur contaminants in excess of 1 wt.% based on feed.

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[0023] The raffinate from the solvent extraction is preferably under-extracted, i.e., the extraction is carried out under conditions such that the raffinate yield is maximized while still removing most of the lowest quality molecules from the feed. Raffinate yield may be maximized by controlling extraction conditions, 5 for example, by lowering the solvent to oil treat ratio and/or decreasing the extraction temperature. The raffinate from the solvent extraction unit is stripped of solvent and then sent to a first hydroconversion unit ( zone) containing a hydroconversion catalyst. This raffinate feed to the first hydroconversion unit is extracted to a dewaxed oil viscosity index of from about 75 to about 105, 10 preferably about 80 to 95.

[0024] In carrying out the extraction process, water may be added to the extraction solvent in amounts ranging from 1 to 10 vol.% such that the extraction solvent to the extraction tower contains from 3 - 10 vol.% water, preferably 4 to 7 vol.% water. In general, feed to the extraction tower is added at the bottom of the 15 tower and extraction/water solvent mixture added at the top and the feed and extraction solvent contacted in counter-current flow. The extraction solvent containing added water may be injected at different levels if the extraction tower contains multiple trays for solvent extraction. The use of added water in the extraction solvent permits the use of low quality feeds while maximizing the 20 paraffin content of the raffinate and the 3+ multi-ring compounds content of the extract. Solvent extraction conditions include a solvent to oil ratio of from 0.5 to 5.0, preferably 1 to 3 and extraction temperatures of from 40 to 120°C, preferably 50 to 100°C.

[0025] If desired, the raffinate feed may be solvent dewaxed under solvent 25 dewaxing conditions prior to entering the first hydroconversion zone. It may be

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advantageous to remove wax from the feed since very little, if any wax is converted in the hydroconversion units. This may assist in debottlenecking the hydroconversion units if throughput is a problem.

[0026] Hydroconversion catalysts are those containing Group VIB metals (based on the Periodic Table published by Fisher Scientific), and non-noble Group VIII metals, i.e., iron, cobalt and nickel and mixtures thereof. These metals or mixtures of metals are typically present as oxides or sulfides on refractory metal oxide supports. Examples of Group VIB metals include molybdenum and tungsten. Other suitable hydrotreating catalysts include bulk metal catalysts such as those containing 30 wt.% or more metals (as metal oxides), based on catalyst, preferably greater than 40 wt.%, more preferably greater than 50 wt.% of metals, based on catalyst wherein the metals include at least one Group VIB or Group VIII metal.

[0027] It is preferred that the metal oxide support be non-acidic so as to control cracking. A useful scale of acidity for catalysts is based on the isomerization of 2-methyl-2-pentene as described by Kramer and McVicker, J. Catalysis, 92, 355(1985). In this scale of acidity, 2-methyl-2-pentene is subjected to the catalyst to be evaluated at a fixed temperature, typically 200° C. In the presence of catalyst sites, 2-methyl-2-pentene forms a carbonium ion. The isomerization pathway of the carbonium ion is indicative of the acidity of active sites in the catalyst. Thus weakly acidic sites form 4-methyl-2-pentene whereas strongly acidic sites result in a skeletal rearrangement to 3-methyl-2-pentene with very strongly acid sites forming 2,3-dimethyl-2-butene. The mole ratio of 3-methyl-2-pentene to 4-methyl-2-pentene can be correlated to a scale of acidity. This acidity scale ranges from 0.0 to 4.0. Very weakly acidic sites will have values near 0.0 whereas very strongly acidic sites will have values approaching 4.0. The

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- catalysis useful in the present process have acidity values of less than about 0.5, preferably less than about 0.3. The acidity of metal oxide supports can be controlled by adding promoters and/or dopants, or by controlling the nature of the metal oxide support, e.g., by controlling the amount of silica incorporated into a 5 silica-alumina support. Examples of promoters and/or dopants include halogen, especially fluorine, phosphorus, boron, yttria, rare-earth oxides and magnesia. Promoters such as halogens generally increase the acidity of metal oxide supports while mildly basic dopants such as yttria or magnesia tend to decrease the acidity of such supports.
- 10 [0028] Suitable metal oxide supports include low acidic oxides such as silica, alumina or titania, preferably alumina. Preferred aluminas are porous aluminas such as gamma or eta having average pore sizes from 50 to 200Å, preferably 75 to 150Å, a surface area from 100 to 300 m<sup>2</sup>/g, preferably 150 to 250 m<sup>2</sup>/g and a pore volume of from 0.25 to 1.0 cm<sup>3</sup>/g, preferably 0.35 to 0.8 cm<sup>3</sup>/g. The supports are 15 preferably not promoted with a halogen such as fluorine as this greatly increases the acidity of the support.

- [0029] Preferred metal catalysts include cobalt/molybdenum (1-5% Co as oxide, 10-25% Mo as oxide) nickel/molybdenum (1-5% Ni as oxide, 10-25% Co as oxide) or nickel/tungsten (1-5% Ni as oxide, 10-30% W as oxide) on alumina. 20 Especially preferred are nickel/molybdenum catalysts such as KF-840.

- [0030] Hydroconversion conditions in the first hydroconversion unit include a temperature of from 320 to 420° C, preferably 340 to 400 °C, a hydrogen partial pressure of 800 to 2500 psig (5.6 to 17.3 MPa), preferably 800 to 2000 psig (5.6 to 13.9 MPa), a space velocity of from 0.2 to 5.0 LHSV, preferably 0.3 to 3.0 LHSV

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and a hydrogen to feed ratio of from 500 to 5000 Scf/B (89 to 890 m<sup>3</sup>/m<sup>3</sup>), preferably 2000 to 4000 Scf/B (356 to 712 m<sup>3</sup>/m<sup>3</sup>).

[0031] The hydroconverted raffinate from the first reactor is then conducted to a second reactor where it is subjected to a cold (mild) hydrofinishing step. The catalyst in this second reactor may be the same as those described above for the first reactor. However, more acidic catalyst supports such as silica-alumina, zirconia and the like may be used in the second reactor. Catalysts may also include Group VIII noble metals, preferably Pt, Pd or mixtures thereof on a metal oxide support which may be promoted. The catalyst and hydroconverted raffinate may be contacted in counter-current flow.

[0032] Conditions in the second reactor include temperatures of from 200 to 360, preferably 290 to 350, a hydrogen partial pressure of from 800 to 2500 psig (5.5 to 17.3 MPa), preferably 800 to 2000 psig (5.5 to 13.9 MPa), a space velocity of from 0.2 to 10 LHSV, preferably 0.7 to 3 LHSV and a hydrogen to feed ratio of from 500 to 5000 Scf/B (89 to 890 m<sup>3</sup>/m<sup>3</sup>), preferably 2000 to 4000 Scf/B (356 to 712 m<sup>3</sup>/m<sup>3</sup>).

[0033] In order to prepare a finished basestock, the hydroconverted raffinate from the second reactor may be conducted to a separator, e.g., a vacuum stripper (or fractionator) to separate out low boiling products. Such products may include hydrogen sulfide and ammonia formed in the first reactor. If desired, a stripper may be situated between the first and second reactors, but this is not essential to produce basestocks according to the invention. If a stripper is situated between the hydroconversion unit and the hydrofinishing unit, then the stripper may be followed by at least one of catalytic dewaxing and solvent dewaxing.

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[0034] The hydroconverted raffinate separated from the separator is then conducted to a dewaxing unit. Dewaxing may be accomplished by catalytic processes under catalytic dewaxing conditions, by solvent dewaxing under solvent dewaxing conditions using a solvent to dilute the hydrofinished raffinate and chilling to crystallize and separate wax molecules, or by a combination of solvent dewaxing and catalytic dewaxing. Typical solvents include propane and ketones. Preferred ketones include methyl ethyl ketone, methyl isobutyl ketone and mixtures thereof. Dewaxing catalysts are molecular sieves, preferably 10 ring molecular sieves, especially unidimensional 10 ring molecular sieves. Preferred molecular sieves include ZSM-5, ZSM-22, ZSM-23, ZSM-35, ZSM-48, ZSM-57, MCM-22, SAPO-11, SAPO-41 and isostructural molecular sieves.

[0035] If a dewaxing catalyst is employed which is tolerant of low boiling products containing nitrogen or sulfur, it may be possible to by-pass the separator and conduct the hydroconverted raffinate directly to a catalytic dewaxing unit and subsequently to a hydrofinishing zone.

[0036] In another embodiment, the dewaxing catalyst may be included within the hydroconversion unit following the hydroconversion catalyst. In this stacked bed configuration, the hydroconverted raffinate in the hydroconversion zone is contacted with the dewaxing catalyst situated within the hydroconversion zone and after the hydroconversion catalyst.

[0037] The solvent/hydroconverted raffinate mixture may be cooled in a refrigeration system containing a scraped-surface chiller. Wax separated in the chiller is sent to a separating unit such as a rotary filter to separate wax from oil. The dewaxed oil is suitable as a lubricating oil basestock. If desired, the dewaxed oil may be subjected to catalytic isomerization/dewaxing to further lower the pour

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point. Separated wax may be used as such for wax coatings, candles and the like or may be sent to an isomerization unit.

[0038] The lubricating oil basestock produced by the process according to the invention is characterized by the following properties: viscosity index of at least 5 about 105, preferably at least 107, NOACK volatility improvement (as measured by DIN 51581) over raffinate feedstock of at least about 3 wt.%, preferably at least about 5 wt.%, at the same viscosity within the range 3.5 to 6.5 cSt viscosity at 100° C, pour point of -15° C or lower, and a low toxicity as determined by IP346 or phase 1 of FDA (c). IP346 is a measure of polycyclic aromatic compounds. Many 10 of these compounds are carcinogens or suspected carcinogens, especially those with so-called bay regions [see Accounts Chem. Res. 17, 332(1984) for further details]. The present process reduces these polycyclic aromatic compounds to such levels as to pass carcinogenicity tests even though the lubricating oil may contain a small amount of residual aromatics content. The FDA (c) test is set forth in 21 CFR 15 178.3620 and is based on ultraviolet absorbances in the 300 to 359 nm range.

[0039] As can be seen from Fig. 1, NOACK volatility is related to VI for any given basestock. The relationship shown in Fig. 1 is for a light basestock (about 20 100N). If the goal is to meet a 22 wt. % NOACK for a 100N oil, then the oil should have a VI of about 110 for a product with typical-cut width, e.g., 5 to 50% off by GCD at 60° C. Volatility improvements can be achieved with lower VI product by decreasing the cut width. In the limit set by zero cut width, one can meet 22% NOACK at a VI of about 100. However, this approach, using distillation alone, incurs significant yield debits.

[0040] Hydrocracking is also capable of producing high VI, and 25 consequently low NOACK basestocks, but is less selective (lower yields) than the

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process of the invention. Furthermore both hydrocracking and processes such as wax isomerization destroy most of the molecular species responsible for the solvency properties of solvent refined oils. The latter also uses wax as a feedstock whereas the present process is designed to preserve wax as a product and does little,  
5 if any, wax conversion.

- [0041] The process of the invention is further illustrated by Fig. 2. The feed  
8 to vacuum pipestill 10 is typically an atmospheric reduced crude from an  
atmospheric pipestill (not shown). Various distillate cuts shown as 12 (light), 14  
(medium) and 16 (heavy) may be sent to solvent extraction unit 30 via line 18.  
10 These distillate cuts may range from about 200° C to about 600° C. The bottoms  
from vacuum pipestill 10 may be sent through line 22 to a coker, a visbreaker or a  
deasphalting extraction unit 20 where the bottoms are contacted with a deasphalting  
solvent such as propane, butane or pentane. The deasphalted oil may be combined  
with distillate from the vacuum pipestill 10 through line 26 provided that the  
15 deasphalted oil has a boiling point no greater than about 600° C or is preferably sent  
on for further processing through line 24. The bottoms from deasphalter 20 can be  
sent to a visbreaker or used for asphalt production. Other refinery streams may also  
be added to the feed to the extraction unit through line 28 provided they meet the  
feedstock criteria described previously for raffinate feedstock.  
20 [0042] In extraction unit 30, the distillate cuts are solvent extracted with n-  
methyl pyrrolidone and the extraction unit is preferably operated in countercurrent  
mode. The solvent-to-oil ratio, extraction temperature and percent water in the  
solvent are used to control the degree of extraction, i.e., separation into a paraffins  
rich raffinate and an aromatics rich extract. The present process permits the  
25 extraction unit to operate to an "under extraction" mode, i.e., a greater amount of

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aromatics in the paraffins rich raffinate phase. The aromatics rich extract phase is sent for further processing through line 32. The raffinate phase is conducted through line 34 to solvent stripping unit 36. Stripped solvent is sent through line 38 for recycling and stripped raffinate is conducted through line 40 to first

5 hydroconversion unit 42.

[0043] The first hydroconversion unit 42 contains KF-840 catalyst which is nickel/molybdenum on an alumina support and available from Akzo Nobel. Hydrogen is admitted to unit or reactor 42 through line 44. Unit conditions are typically temperatures of from 340-420° C, hydrogen partial pressures from 800 to 10 2000 psig, space velocity of from 0.5 to 3.0 LHSV and a hydrogen to feed ratio of from 500 to 5000 Scf/B. Gas chromatographic comparisons of the hydroconverted raffinate indicate that almost no wax isomerization is taking place. While not wishing to be bound to any particular theory since the precise mechanism for the 15 VI increase which occurs in this stage is not known with certainty, it is known that heteroatoms are being removed, aromatic rings are being saturated and naphthene rings, particularly multi-ring naphthenes, are selectively eliminated.

[0044] Hydroconverted raffinate from unit 42 is sent through line 46 to second unit or reactor 50. Reaction conditions in unit are mild and include a temperature of from 200-320° C, a hydrogen partial pressure of from 800 to 2000 20 psig, a space velocity of 1 to 5 LHSV and a hydrogen feed rate of from 500 to 5000 Scf/B. This mild or cold hydrofinishing step further reduces toxicity to very low levels.

[0045] Hydroconverted raffinate is then conducted through line 52 to separator 54. Light liquid products and gases are separated and removed through 25 line 56. The remaining hydroconverted raffinate is conducted through line 58 to

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dewaxing unit 60. Dewaxing may occur by the use of solvents (introduced through line 62) which may be followed by cooling, by catalytic dewaxing or by a combination thereof. Catalytic dewaxing involves hydrocracking and/or hydroisomerization as a means to create low pour point lubricant basestocks.

- 5 Solvent dewaxing with optional cooling separates waxy molecules from the hydroconverted lubricant basestock thereby lowering the pour point. Hydroconverted raffinate is preferably contacted with methyl isobutyl ketone followed by the DILCHILL Dewaxing Process developed by Exxon. This method is well known in the art. Finished lubricant basestock is removed through line 64
- 10 and waxy product through line 66.

[0046] In the process according to the invention, any waxy components in the feed to extraction unit 30 passes virtually unchanged through the hydroconversion zone and is conducted to dewaxing unit 60 where it may be recovered as product.

- [0047] Toxicity of the basestock is adjusted in the cold hydrofinishing step.
- 15 For a given target VI, the toxicity may be adjusted by controlling the temperature and pressure.

- [0048] The basestocks produced according to the invention have unique properties. The basestocks have excellent volatility/viscosity properties typically observed for basestocks having much higher VI. These and other properties are the result of having multi-ring aromatics selectively removed. The presence of even small amounts of these aromatics can adversely impact properties of basestocks including viscosity, VI, toxicity and color.

[0049] The basestocks also have improved Noack volatility when compared to Group II hydrocrackates of the same viscosity. When formulated with

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conventional additive packages used with passenger car motor oils, the finished oils have excellent oxidation resistance, wear resistance, resistance to high temperature deposits and fuel economy properties as measured by engine test results. The basestocks according to the invention can have other uses such as automatic  
5 transmission fluids, agricultural oils, hydraulic fluids, electrical oils, industrial oils, heavy duty engine oils and the like.

[0050] The invention is further illustrated by the following non-limiting examples.

**Example 1**

10 [0051] The route to improved volatility at a fixed viscosity is to selectively increase the VI of the base oil. Molecularly this requires that the base oil become relatively richer in isoparaffinic species. They have the highest boiling points at a given viscosity. Mid boiling point can be increased (i.e. volatility decreased) by increasing the cut point on a particular sample, thereby raising viscosity. To  
15 maintain viscosity at a given cut width and increase mid boiling point necessarily means that the basestock have fewer clustered rings, either naphthenic or aromatic, and more paraffinic character. Isoparaffins are preferred because they have much higher boiling points for the same viscosity versus naphthenes and aromatic multi-rings. They also have lower melting points than normal paraffins. Most crudes  
20 have an inherently high population of clustered rings that separations-based processing alone cannot selectively remove to achieve the quality required for modern passenger car motor oils (PCMO's) (i.e. VI of 110 to 120+) in an acceptable yield.

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[0052] Thermal diffusion is a technique that can be used for separating hydrocarbon mixtures into molecular types. Although it has been studied and used for over 100 years, no really satisfactory theoretical explanation for the mechanism of thermal diffusion exists. The technique is described in the following literature:

- 5 L. Jones and E. C. Milberger., Industrial and Engineering Chemistry, p. 2689, Dec. 1953, T. A. Warhall and F. W. Melpolder., Industrial and Engineering Chemistry, p. 26, Jan. 1962 and H. A. Harner and M. M. Bellamy, American Laboratory, p. 41, Jan. 1972 and references therein.

[0053] The thermal diffusion apparatus used in the current application was a 10 batch unit constructed of two concentric stainless steel tubes with an annular spacing between the inner and outer tubes of 0.012 in. The length of the tubes was approximate 6 ft. The sample to be tested is placed in the annular space between the inner and outer concentric tubes. The inner tube had an approximate outer diameter of 0.5 in. Application of this method requires that the inner and outer 15 tubes be maintained at different temperatures. Generally temperatures of 100 to 200°C for the outer wall and about 65°C for the inner wall are suitable for most lubricating oil samples. The temperatures are maintained for periods of 3 to 14 days.

[0054] While not wishing to be bound to any particular theory, the thermal 20 diffusion technique utilizes diffusion and natural convention, which arises from the temperature gradient established between the inner and outer walls of the concentric tubes. Higher VI molecules diffuse to the hotter wall and rise. Lower VI molecules diffuse to the cooler inner walls and sink. Thus a concentration gradient of different molecular densities (or shapes) is established over a period of days. In 25 order to sample the concentration gradient, sampling ports are approximately

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equidistantly spaced between the top and bottom of the concentric tubes. Ten is a convenient number of sampling ports.

- [0055] Two samples of oil basestocks were analyzed by thermal diffusion techniques. The first is a conventional 150N basestock having a 102 VI and 5 prepared by solvent extraction/dewaxing methods. The second is a 112 VI basestock prepared by the raffinate hydroconversion (RHC) process according to the invention from a 100 VI, 250N raffinate. The samples were allowed to sit for 7 days after which samples were removed from sampling ports 1-10 spaced from top to bottom of the thermal diffusion apparatus.
- 10 [0056] The results are shown in Fig. 3. Fig. 3 demonstrates that even a "good" conventional basestock having a 102 VI contains some very undesirable molecules from the standpoint of VI. Thus sampling ports 9 and especially 10 yield molecular fractions containing very low VI's. These fractions which have VI's in the -25 to -250 range likely contain multi-ring naphthenes. In contrast, the 15 RHC product according to the invention contains far fewer multi-ring naphthenes as evidenced by the VI's for products obtained from sampling ports 9 and 10. Thus the present RHC process selectively destroys multi-ring naphthenes and multi-ring aromatics from the feed without affecting the bulk of the other higher quality molecular species. The efficient removal of the undesirable species as typified by 20 port 10 is at least partially responsible for the improvement in NOACK volatility at a given viscosity
- [0057] The excellent properties of basestocks according to invention are given in the following table.

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**TABLE A**

Sample Number	I	II
Viscosity Index	116	114
Viscosity, @ 100C, cSt	4.5	5.9
Volatility, Noack, wt%	14	8
Pour Point, °C	-18	-18
Saturates by HPLC, wt%	98	97

**Example 2**

[0058] This example compares a low acidity catalyst useful in the process according to the invention versus a more acidic catalyst. The low acidity catalyst is KF-840 which is commercially available from Akzo Nobel and has an acidity of 0.05. The other catalyst is a more acidic, commercially available catalyst useful in hydrocracking processes having an estimated acidity of 1 and identified as Catalyst A. The feed is a 250N waxy raffinate having an initial boiling point of 335° C, a mid-boiling point of 463° C and a final boiling point of 576° C, a dewaxed oil viscosity at 100° C of 8.13 cSt, a dewaxed oil VI of 92 and a pour point of -19° C. The results are shown in Tables 1 and 2.

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Table 1

Comparison at Similar Conditions

	<u>Operating Conditions</u>	<u>Catalyst</u>	
		<u>Catalyst A</u>	<u>KF-840</u>
5	Temperature, °C	355	360
	LHSV, v/v/hr	0.5	0.5
	H <sub>2</sub> pressure psig	800	800
	H <sub>2</sub> to feed Scf/B	1600	1300
10	Conversion to 370° C-, wt.%	22	11
	Product VI	114	116

Table 2

Comparison at Similar Conversion

	<u>Operating Conditions</u>	<u>Catalyst</u>	
		<u>Catalyst A</u>	<u>KF-840</u>
20	Temperature	345	360
	LHSV, v/v/hr	0.5	0.5
	H <sub>2</sub> pressure psig	800	800
	H <sub>2</sub> to feed Scf/B	1600	1300
25	Conversion to 370° C-, wt.%	11	11
	Product VI	107	116

[0059] As can be seen from Table 1, if reaction conditions are similar, then

30 Catalyst A gives a much higher conversion. If conversion is held constant (by adjusting reaction conditions), then the VI of the product from Catalyst A is much lower. These results show that while more acidic catalysts have higher activity, they have much lower selectivity for VI improvement.

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**Example 3**

- [0060] This example shows that processes like lubes hydrocracking which typically involve a more acid catalyst in the second of two reactors is not the most effective way to improve volatility properties. The results for a 250N raffinate feed having a 100 VI DWO is shown in Table 3. Product was topped to the viscosity required and then dewaxed.

**Table 3**

<b>2 Reactor 2 Catalyst *</b> <b>Two Stage Process</b>				<b>Raffinate Hydroconversion **</b>		
<b>Yield</b>	<b>Viscosity,cSt @ 100°C</b>	<b>NOACK ***</b>	<b>Yield</b>	<b>Viscosity,cSt @ 100°C</b>	<b>NOACK Volatility</b>	
30.5	6.500	3.3	69.7	6.500	3.6	

- \* 1st stage conditions: Ni/Mo catalyst, 360°C, 800 psig H<sub>2</sub>, 0.5 LHSV, 1200 Scf/B  
 10 2nd stage conditions: Ni/Mo/Silica alumina catalyst, 366°C, 2000 psig H<sub>2</sub>, 1.0 LHSV, 2500 Scf/B  
 \*\* Conditions: KF-840 catalyst, 353°C, 800 psig H<sub>2</sub>, 0.49 LHSV, 1200 Scf/B  
 \*\*\* Estimated by GCD

15

- [0061] With an acid silica-alumina type catalyst in the second reactor of the 2 reactor process, the yield of product of a given volatility at the same viscosity is lower than the yield of the process of the invention using raffinate feeds. This confirms that a low acidity catalyst is required to achieve low volatility selectively.

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Example 4

- [0062] Many current commercially available basestocks will have difficulty meeting future engine oil volatility requirements. This example demonstrates that conventional extraction techniques vs. hydroconversion techniques suffer from 5 large yield debits in order to decrease NOACK volatility. NOACK volatility was estimated using gas chromatographic distillation (GCD) set forth in ASTM 2887. GCD NOACK values can be correlated with absolute NOACK values measured by other methods such as DIN 51581.
- [0063] The volatility behavior of conventional basestocks is illustrated using 10 an over-extracted waxy raffinate 100N sample having a GCD NOACK volatility of 27.8 (at 3.816 cSt viscosity at 100° C). The NOACK volatility can be improved by removing the low boiling front end (Topping) but this increases the viscosity of the material. Another alternative to improving NOACK volatility is by removing 15 material at both the high boiling and low boiling ends of the feed to maintain a constant viscosity (Heart-cut). Both of these options have limits to the NOACK volatility which can be achieved at a given viscosity and they also have significant yield debits associated with them as outlined in the following table;

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Table 4

Distillation Assay of 100N Over-Extracted Waxy Raffinate (103 VI DWO \*)

NOACK				
	<u>Processing</u>	<u>Volatility, wt.% **</u>	<u>Yield, %</u>	<u>Viscosity, cSt @ 100° C</u>
5	None	27.8	100	3.816
	Topping	26.2	95.2	3.900
	Heart-cut	22.7	58.0	3.900
	Heart-cut	22.4	50.8	3.900
	Heart-cut	21.7	38.0	3.900

\* DWO = dewaxed oil

\*\* estimated by GCD

15    Example 5

[0064]       The over-extracted feed from Example 4 was subjected to raffinate hydroconversion under the following conditions: KF-840 catalyst at 353° C, 800 psig H<sub>2</sub>, 0.5 LHSV, 1200 Scf/B. Raffinate hydroconversion under these conditions increased the DWO VI to 111. The results are given in Table 5.

Table 5

Distillation Assay of Hydroconverted Waxy Raffinate (103VI to 111 VI DWO)

		<u>NOACK *</u>	<u>Yield, %</u>	<u>Viscosity, cSt @ 100°C</u>
	<u>Processing</u>	<u>Volatility</u>		
25	None	38.5	99.9	—
	Topping	21.1	76.2	3.900
	Heart-cut	20.9	73.8	3.900
	Heart-cut	19.9	62.8	3.900
	Heart-cut	19.2	52.2	3.900
	Heart-cut	18.7	39.6	3.900

\* Estimated by GCD

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These results demonstrate that raffinate hydroconversion can achieve lower NOACK volatility much more selectivity than by distillation alone, e.g., more than double the yield at 21 NOACK. Furthermore, since the process of the invention removes poorer molecules, much lower volatilities can be achieved than by  
 5 distillation alone.

#### Example 6

[0065] This example illustrates the preferred feeds for the raffinate hydroconversion (RHC) process. The results given in Table 6 demonstrate that there is an overall yield credit associated with lower VI raffinates to achieve the  
 10 same product quality (110 VI) after topping and dewaxing. The table illustrates the yields achieved across RHC using 100N raffinate feed.

Table 6

<u>Feed VI</u>	<u>NOACK Volatility</u>	<u>Viscosity cSt @ 100°C</u>	<u>Extraction Yield</u>	<u>Hydroprocessing Yield</u>	<u>Yield of Waxy Product (on distillate)</u>
103 *	21.1	3.900	53.7	76.2	40.9
92 **	21.1	4.034	73.9	63.8	47.1

15

\* KF-840 catalyst, 353° C, 800 psig H<sub>2</sub>, 0.5 LHSV, 1200 Scf/B

\*\* KF-840 catalyst, 363-366° C, 1200 psig H<sub>2</sub>, 0.7 LHSV, 2400 Scf/B

The yield to get to a 110 VI product directly from distillate by extraction alone is  
 20 only 39.1% which further illustrates the need to combine extraction with hydroprocessing.

[0066] While under-extracted feeds produce higher yields in RHC, use of distillates as feeds is not preferred since very severe conditions (high temperature

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and low LHSV) are required. For example, for a 250N distillate over KF-840 at 385° C, 0.26 LHSV, 1200 psi H<sub>2</sub>, and 2000 Scf/B gas rate, only 104 VI product was produced.

[0067] Also, combinations of distillate hydroprocessing (to reach an 5 intermediate VI) then extraction to achieve target VI is not preferred. This is because the extraction process is nonselective for removal of naphthenes created from aromatics in the distillate hydroprocessing stage.

**Example 7**

[0068] In the raffinate hydroconversion process according to the invention, 10 the first reaction zone is followed by a second cold hydrofining (CHF) zone. The purpose of CHF is to reduce the concentration of molecular species which contribute to toxicity. Such species may include 4- and 5-ring polynuclear aromatic compounds, e.g., pyrenes which either pass through or are created in the first reaction zone. One of the tests used as an indicator of potential toxicity is the FDA 15 "C" test (21 CFR 178.3620) which is based on absorbances in the ultraviolet (UV) range of the spectrum. The following table demonstrates that CHF produces a product with excellent toxicological properties, which are much lower than the acceptable maximum values.

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Table 7

		<u>FDA "C"</u>			
		<u>280-289</u>	<u>290-299</u>	<u>300-359</u>	<u>360-400</u>
5		<u>nm</u>	<u>nm</u>	<u>nm</u>	<u>nm</u>
	FDA "C" MAX (Absorbance Units)	0.7	0.6	0.4	0.09
<u>Sample</u>					
CHF Products					
10	DLM-120	0.42	0.25	0.22	0.024
	(CHF Process Conditions: 3 v/v/h, 260° C, 800 psig, 1200 Scf/B Hydrogen (containing N=38 wppm, S=0.6 wt.% on feed))				
15	DLM-118	0.26	0.14	0.11	0.013
	(CHF Process Conditions: 3 v/v/h, 260° C, 800 psig, 1200 Scf/B Hydrogen)				
CHF Products					
	DLM-115	0.36	0.23	0.17	0.016
	(CHF Process Conditions: 2 v/v/h, 260° C, 800 psig, 1200 Scf/B)				
20					

These results demonstrate that a CHF step enables the product to easily pass the FDA "C" test.

#### Example 8

[0069] Example 8 shows that products from RHC have outstanding toxicological properties versus basestocks made either by conventional solvent processing or hydrocracking. Besides FDA "C", IP 346 and modified Ames (mutagenicity index) are industry wide measures of toxicity. The results are shown in Table 8.

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Table 8

	Commercial Solvent Extracted Basestock		Commercial Hydrocracked Basestock		RHC Basestock	
			100N	250N	100N	250N
	100N	250N	100N	250N	100N	250N
5	IP346, wt.%	0.55	0.55	0.67	0.11	0.15
	Mod Ames, MI	0.0	0.0	0.0	0.0	0.0
10	FDA (C) (phase I)	0.22	0.22	0.21	0.02	0.03
	(300-359 nm)					

[0070] The results in Table 8 demonstrate that RHC produces a basestock with much improved toxicological properties over conventional solvent extracted or hydrocracked basestocks.

#### Example 9

[0071] A 250N distillate was extracted with NMP under the conditions set forth in Table 9. Water was added to the NMP solvent at 5 vol.% according to the invention to favor high yield of raffinate and at 0.5 vol.% as a comparative example of typical raffinate under normal extraction conditions.

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**TABLE 9**  
**Dewaxed (-18°C Pour) Raffinate Composition: 250N**

<u>Countercurrent Extraction</u>	<u>Example 10</u>	<u>Comparative Example 10</u>
<b>Conditions</b>		
Treat, LV%	275	90
% H <sub>2</sub> O in Solvent	5	0.5
Temperature, °F (°C) (Bottom)	176 (80)	124 (51)
Gradient, F	11	11
<b>Yield, LV%</b>		
	66	61
<b>Quality</b>		
VI	97	97
<b>Composition, LV%</b>		
Saturates		
0-R	24	22
1-R	15	13
2-R	11	11
3-R	9	11
4-R	5	7
5+R	2	2
Total Saturates	<u>66</u>	<u>66</u>
Aromatics		
1-R	18	18
2-R	3	3
3-R	1	1
4-R	0.5	0.5
5-R	0.5	0.5
Thiopheno	<u>4</u>	<u>4</u>
Total Aromatics	<u>27</u>	<u>27</u>
Unidentified	7	7

[0072] The data demonstrate that the raffinate according to the invention extracted with NMP containing 5 LV% water provides a superior feed to the first hydroconversion unit. The raffinate feed results in about 5 LV% more yield (at 97 VI) and about 4 LV% more paraffin plus 1-ringnaphthenes and about 4 LV% less 5 3+ ring naphthenes.

[0073] Based on the data in Table 9, RHC feed should be extracted at low severity to target a maximum of 3+ ring compounds (aromatics and naphthenes) rather than to target VI. The highest yield of such raffinate will be obtained using 10 high water/high treat extraction conditions. Optimization of extraction could provide 5 LV% or more of waxy raffinate which can be fed to the hydroconversion process without any process debits.

#### Example 10

[0074] A unique feature of the products from the present process is that both 15 yield and the crucial volatility/viscosity properties are improved by using under-extracted feeds. In other processes, yield improvements are generally at the expense of basestock quality. Figure 4 is a graph illustrating the raffinate feed quality as a function of yield and viscosity. A 250N distillate was extracted, hydroprocessed, vacuum stripped and dewaxed to produce a constant VI (113), 20 7.0% NOACK volatility basestock with a -18°C pour point. As shown in Fig. 4, preferred feeds have a DWO VI between about 80 to about 95.

#### Example 11

[0075] Figure 5 illustrates that the Group II products from the current invention most closely follow the volatility-viscosity relationship of Group III

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basestocks (having much higher VI's). The Figure also compares this behavior with the much poorer volatility-viscosity relationship of a standard Group II hydrocrackate. The basestocks of the invention have unique properties in that they have VI <120 and yet have viscosity/volatility properties comparable to Group III 5 basestocks (>120 VI). Those basestocks characterized as having viscosities in the range 3.5 to 6.0 cSt at 100°C are defined by the equation  $N = (32 - (4)(\text{viscosity at } 100^\circ\text{C})) \pm 1$  where N is the Noack volatility.

[0076] Fig. 6 shows that the Group II basestock according to the invention has a superior Noack volatility compared to the conventional Group II basestock 10 based on 4 cSt oils.

#### Example 12

[0077] It is well known that basestock quality can affect finished oil performance in certain standard industry tests. The performance of the present basestocks in fully formulated GF-2 type 5W-30 formulations was therefore 15 assessed in both bench and sequence engine tests.

[0078] An in-house bench oxidation test was first used to assess the resistance to oxidative thickening offered by the present basestocks compared to conventionally processed Group I stocks. The test oil is subjected to air sparging in 20 the presence of a soluble iron catalyst at 165°C; the change in 40°C kinematic viscosity with time is recorded and an estimate of the hours to reach 375% viscosity increase is made. Two different additive systems were compared in the conventional Group I and in the present basestocks (designated as "EHC") in Table 10 below:

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**TABLE 10**

Blend Number:	1	2	3	4
Performance Additive System	A	B	A	B
Basestocks	Group I	Group I	EHC	EHC
Oxidation Screener, est. hrs to 375% vis. increase	57.5	82.5	72.0	83.5

- Additive systems A and B are conventional additive packages. Additive system A
- 5 includes a detergent, dispersant, antioxidant, friction modifier, demulsifier, VI improver and antifoamant. Additive system B includes a detergent, dispersant, antioxidant, friction modifier, antifoamant and VI improver. The individual components within each additive package may vary according to the manufacturer.
- The basestocks according to the invention were found to provide significant
- 10 improvement in oxidation performance over the conventional basestock with additive system 'A', and somewhat smaller improvement with additive system 'B'.

- [0079] The oxidation screener can only provide a general indication of oxidation resistance. To confirm engine performance, Sequence IIIE tests were
- 15 conducted on the Group I and on the EHC stocks in 5W-30 formulations using additive system 'B'. The Sequence IIIE test is a standard industry bench engine test which assesses oxidation resistance, wear and high temperature deposits (ASTM D 5533). The results, shown in Table 11, indicated that the EHC basestocks provided improved oxidation control (beyond that predicted in the bench screener), as well as
- 20 good control of high temperature deposits.

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TABLE 11

Blend Number:	5	6	
Performance Additive System	B	B	
Basestocks	Group I	EHC	
<u>Seq. IIIE</u>			<u>Limits</u>
% Viscosity Increase @ 64 hr	182	63	375 max
Hours to 375% vis. Increase	71.2	78.9	64 min
Avg. Engine Sludge, merits	9.57	9.51	9.2 min
Avg. Piston Skirt Varnish, merits	9.31	9.17	8.9 min
Oil Ring Land Deposits, merits	3.02	3.96	3.5 min
Stuck Lifters	none	none	none
Scuffed/Worn Cam or Lifters	none	none	none
Avg. Cam+Lifter Wear, microns	15.4	9	30
Max. Cam+Lifter Wear, microns	74	20	64
Oil Consumption, L	3.85	2.55	Report

[0080] Repeat IIIE testing on the Group I, 5W-30, showed that this additive system could meet the wear and ring land deposit requirements in conventionally

5 refined stocks. However, viscosity increase remained better for the EHC formulations, either alone, or in combination with Group I basestocks as shown in Figure 7. Oil consumption was also consistently lower for the EHC formulation, probably due to the lower volatility of these basestocks.

#### 10 Example 14

[0081] The Sequence VE is another key engine test which measures sludge, varnish and wear under relatively low engine operating temperatures. Comparative tests were conducted on SAE 5W-30 formulations made with Group I and with EHC stocks in another additive system. These indicated that the EHC basestocks

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provided at least as good control of sludge and better average varnish than the conventional stock (Table 12).

**TABLE 12**

5

Blend Number:	7	8	
Performance Additive System	C	C	
Basestocks	Group I	EHC	
<u>Seq. VE</u>			<u>Limits</u>
Avg. Engine Sludge, merits	9.14	9.49	9.0 min
Rocker Cover Sludge, merits	8.28	9.04	7.0 min
Piston Skirt Varnish, merits	7.02	6.90	6.5 min
Avg. Engine Varnish, merits	5.43	6.25	5.0 min
Oil Screen Clogging, %	3	0	20 max
Hot Stuck Rings	none	none	none
Avg. Cam Wear, microns	83.6	18	130 max
Max. Cam Wear, microns	231	27	380 max

#### Example 15

[0082] Lubricant fuel economy and fuel economy retention has become of increasing importance to original equipment manufacturers, and this is reflected in 10 the greater demands of standard industry tests. Proposed Sequence VIB fuel economy limits from the draft ILSAC GF-3 specification are shown in Table 13 along with single test results on SAE 5W-20, 5W-30 and 10W-30 prototype formulations containing EHC basestocks and a single additive system. It is apparent that the EHC stocks offer the potential to meet these very demanding 15 limits.

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TABLE 13

Performance Additive System	D	
Basestocks	EHC	
<u>5W-20</u>		<u>Originally Proposed Limits</u>
16 hr, % Fuel Economy Improvement	2.0	2.0 min
96 hr, % Fuel Economy Improvement	1.8	1.7 min
<u>5W-30</u>		
16 hr, % Fuel Economy Improvement	1.7	1.7 min
96 hr, % Fuel Economy Improvement	1.4	1.4 min
<u>10W-30</u>		
16 hr, % Fuel Economy Improvement	1.4*	1.3 min
96 hr, % Fuel Economy Improvement	1.1*	1.0 min

\* referenced engine stand, latest Sequence VIB industry Severity Bias Correction Factors applied.

**CLAIMS:**

1. A process for producing a lubricating oil basestock which comprises:
  - (a) conducting a lubricating oil feedstock, said feedstock being a distillate fraction, to a solvent extraction zone and under-extracting the feedstock to form an under-extracted raffinate wherein the extraction zone solvent contains water added in the amount from about 1 to about 10 vol.%, based on extraction solvent, such that the extraction solvent contains from 3 to 10 vol.% water;
  - (b) stripping the under-extracted raffinate of solvent to produce an under-extracted raffinate feed having a dewaxed oil viscosity index from about 75 to about 105;
  - (c) passing the raffinate feed to a first hydroconversion zone and processing the raffinate feed in the presence of a non-acidic catalyst at a temperature of from about 320 to about 420°C, a hydrogen partial pressure of from about 800 to about 2500 psig (5.6 to 17.3 mPa), space velocity of about 0.2 to about 5.0 LHSV, and a hydrogen to feed ratio of from about 500 to about 5000 Scf/B (89 to 890 m<sup>3</sup>/m<sup>3</sup>) to produce a first hydroconverted raffinate; and
  - (d) passing the first hydroconverted raffinate to a second reaction zone and conducting cold hydrofinishing of the first hydroconverted raffinate in the presence of a hydrofinishing catalyst at a temperature of from about 200 to about 360°C, a hydrogen partial pressure of from about 800 to about 2500 psig (5.6 to 17.3 mPa), a space velocity of from about 1 to about 10 LHSV, and a hydrogen to feed ratio of from about 500 to about 5000 Scf/B (89 to 890 m<sup>3</sup>/m<sup>3</sup>) to produce a hydrofinished raffinate.

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2. The process of claim 1 wherein the solvent extraction zone includes an extraction solvent selected from at least one of N-methyl-2-pyrrolidone, furfural and phenol.

3. The process of claim 2 wherein the extraction zone conditions include a solvent: oil ratio is from 0.5 to 5.0.

4. The process of claim 1 wherein the raffinate feed has a dewaxed oil viscosity index from about 80 to about 95.

5. The process of claim 1 wherein the non-acidic catalyst has an acidity less than about 0.5, said acidity being determined by the ability of the catalyst to convert 2-methyl-2-pentene to 3-methyl-2-pentene and 4-methyl-2-pentene and is expressed as the mole ratio of 3-methyl-2-pentene to 4-methyl-2-pentene.

6. The process of claim 1 wherein the non-acidic catalyst in the first hydroconversion zone is at least one of a Group VIB metal and non-noble Group VIII metal.

7. The process of claim 1 wherein the space velocity in the first hydroconversion zones is from about 0.3 to 3.0 LHSV.

8. The process of claim 1 wherein the temperature in the hydrofinishing zone is from about 290 to 350°C.

9. The process of claim 1 wherein the catalyst in the hydrofinishing zone includes at least one Group VIII noble metal.

10. The process of claim 9 wherein the catalyst is Pt, Pd or a mixture thereof.

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11. The process of claim 1 wherein the first hydroconverted raffinate is passed to a separator to separate low boiling products from hydroconverted raffinate prior to passing to the hydrofinishing reaction zone.

12. The process of claim 11 wherein hydroconverted raffinate from the 5 separator is passed to a dewaxing zone and subjected to at least one of solvent dewaxing and catalytic dewaxing prior to passing to the hydrofinishing zone.

13. The process of claim 12 wherein catalytic dewaxing is accomplished with a dewaxing catalyst containing at least one 10 ring molecular sieve.

14. The process of claim 1 wherein the first hydroconverted raffinate is 10 passed to a dewaxing zone and catalytically dewaxed using a sulfur and nitrogen tolerant molecular sieve prior to passing to the hydrofinishing zone.

15. The process of claim 1 wherein the hydrofinished raffinate is passed to a separator to separate low boiling products from the hydrofinished raffinate to produce a second hydrofinished raffinate.

15 16. The process of claim 15 wherein the second hydrofinished raffinate is passed to a dewaxing zone and subjected to at least one of solvent dewaxing and catalytic dewaxing to produce a dewaxed second hydrofinished raffinate.

17. The process of claim 16 wherein the catalytic dewaxing is accomplished with a dewaxing catalyst containing at least one 10 ring molecular sieve.

20 18. The process of claim 1 wherein the hydrofinished raffinate is passed to a dewaxing zone and dewaxed using a sulfur and nitrogen tolerant molecular sieve.

19. The process of claim 16 wherein the dewaxed second hydrofinished raffinate is further hydrofinished in a second hydrofinishing zone.

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20. The process of claim 1 wherein the under-extracted raffinate feed is solvent dewaxed under solvent dewaxing conditions prior to entering the first hydroconversion zone.

21. The process of claim 1 additionally comprising adding additives to the 5 lubricating oil basestock.

22. The process of claim 21 wherein the additives comprise at least one detergent, dispersant, antioxidant, friction modifier, demulsifier, VI improver and antifoamant.

23. The process of claim 1 wherein first hydroconversion zone additionally 10 contains a catalytic dewaxing catalyst.

24. A process for producing a lubricating oil basestock which comprises:

(a) conducting a lubricating oil feedstock, said feedstock being a distillate fraction, to a solvent extraction zone and under-extracting the feedstock to form an under-extracted raffinate wherein the extraction zone solvent contains 15 water added in the amount from about 1 to about 10 vol.%, based on extraction solvent, such that the extraction solvent contains from 3 to 10 vol.% water;

(b) stripping the under-extracted raffinate of solvent to produce an under-extracted raffinate feed having a dewaxed oil viscosity index from about 75 to about 105;

20 (c) passing the raffinate feed to a first hydroconversion zone and processing the raffinate feed in the presence of a non-acidic catalyst at a temperature of from about 320 to about 420°C, a hydrogen partial pressure of from about 800 to about 2500 psig (5.6 to 17.3 mPa), space velocity of about 0.2 to about

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5.0 LHSV, and a hydrogen to feed ratio of from about 500 to about 5000 Scf/B (89 to 890 m<sup>3</sup>/m<sup>3</sup>) to produce a first hydroconverted raffinate;

- 5       (d) passing at least a portion of the first hydroconverted raffinate to a dewaxing zone and conducting at least one of catalytic and solvent dewaxing under dewaxing conditions to produce a dewaxed hydroconverted raffinate; and
- 10      (e) passing the dewaxed hydroconverted raffinate to a second reaction zone and conducting cold hydrofinishing of the first hydroconverted raffinate in the presence of a hydrofinishing catalyst at a temperature of from about 200 to about 360°C, a hydrogen partial pressure of from about 800 to about 2500 psig (5.6 to 17.3 mPa), a space velocity of from about 1 to about 10 LHSV, and a hydrogen to feed ratio of from about 500 to about 5000 Scf/B (89 to 890 m<sup>3</sup>/m<sup>3</sup>) to produce a hydrofinished raffinate.

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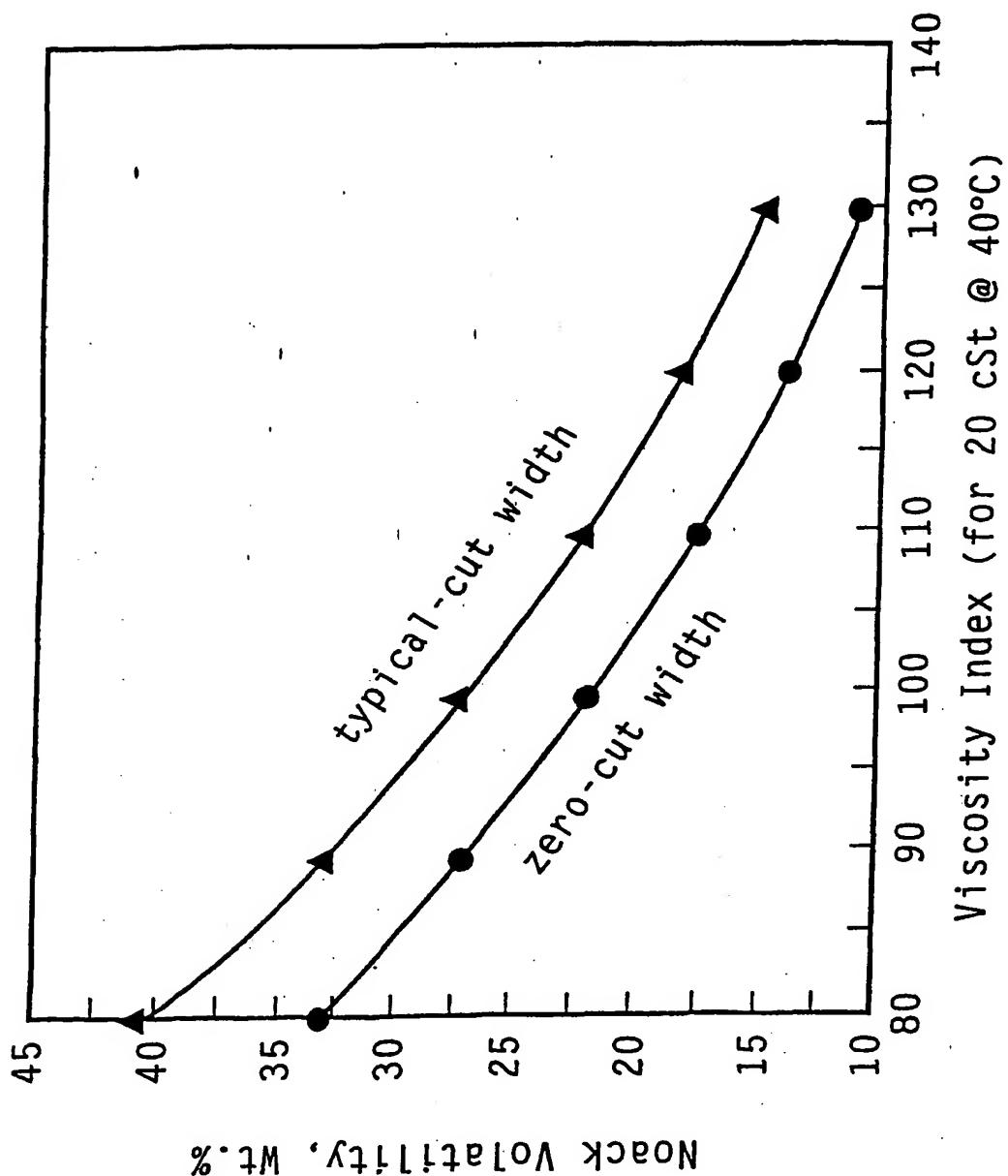


FIG. 1

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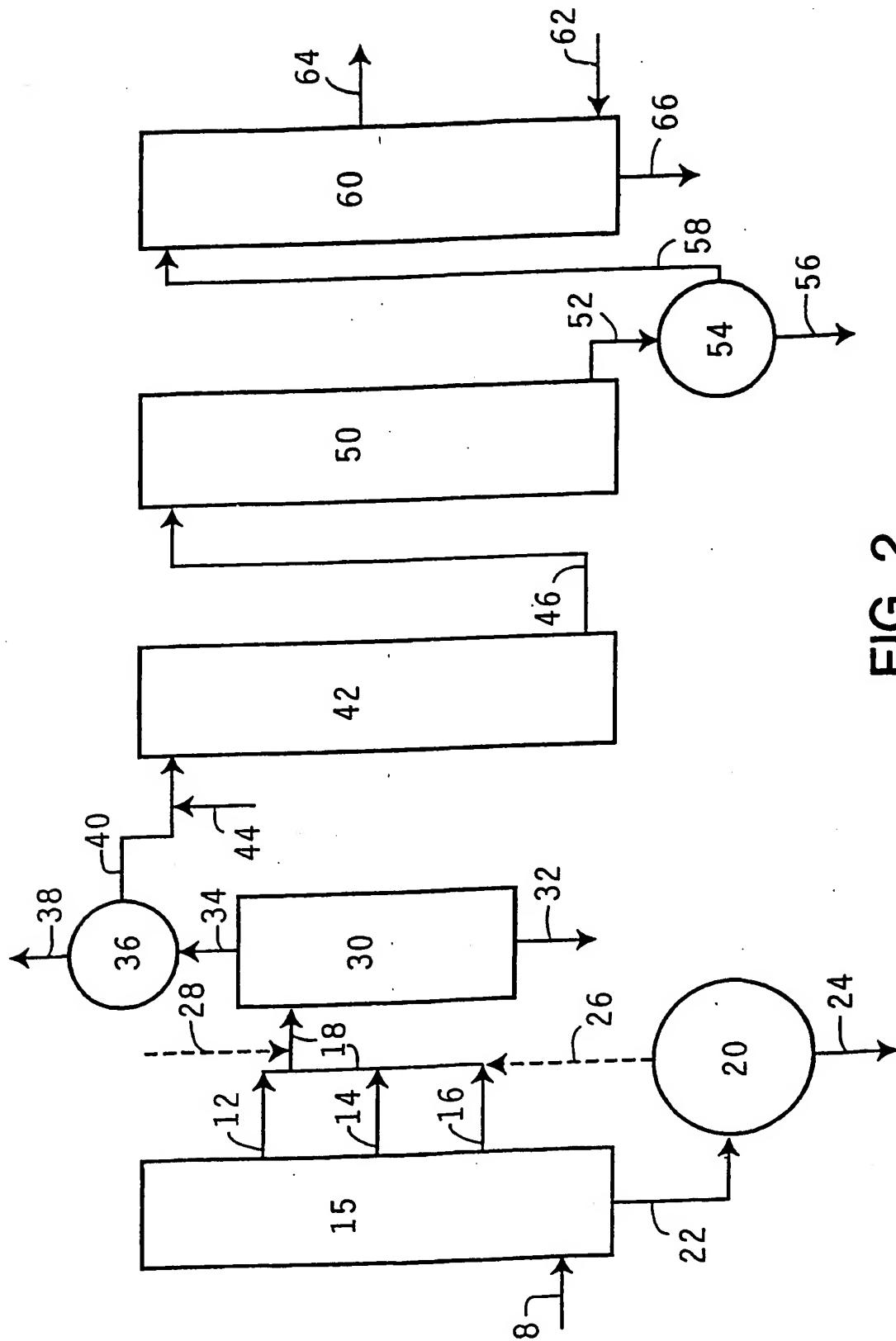


FIG. 2

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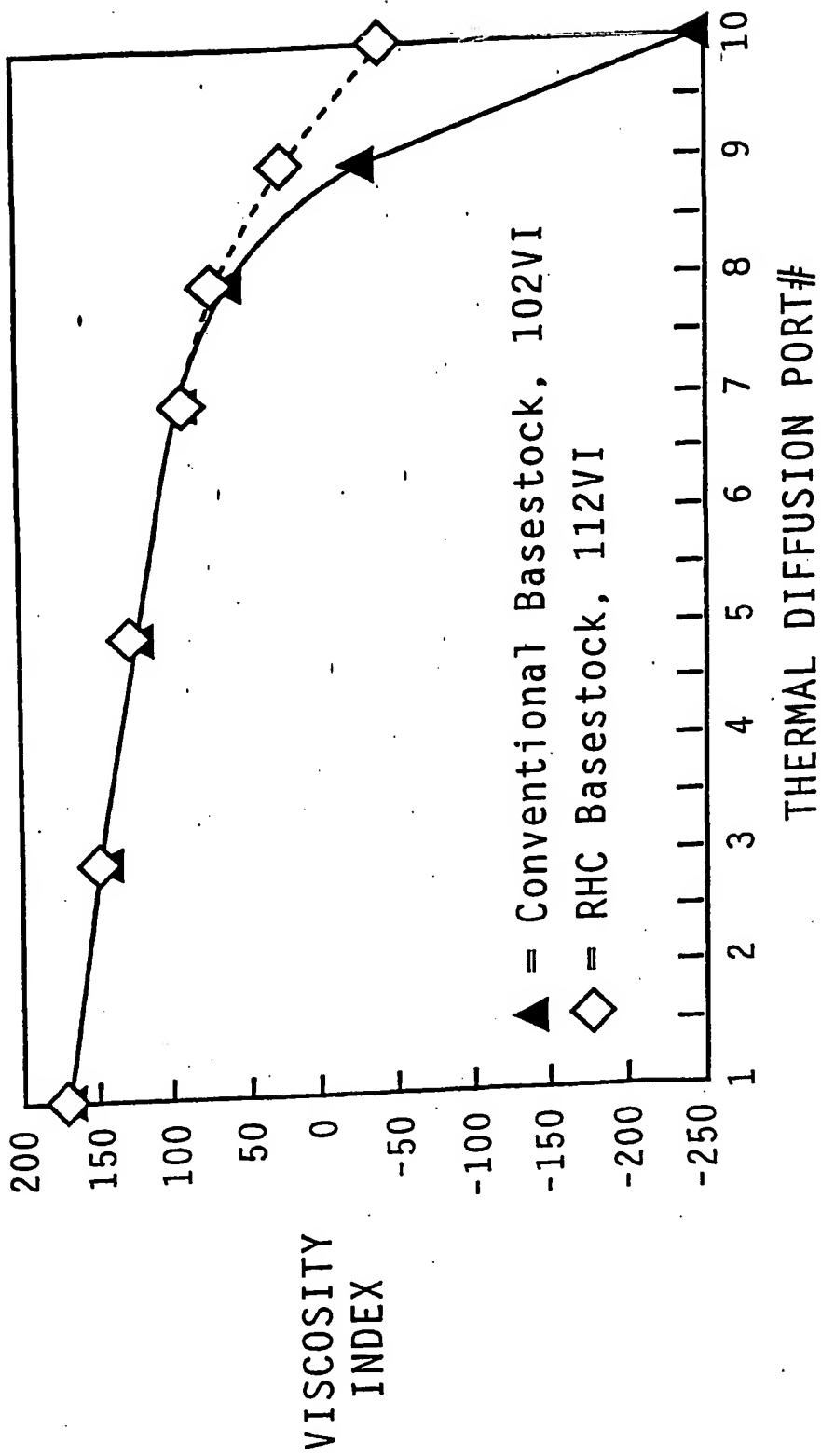
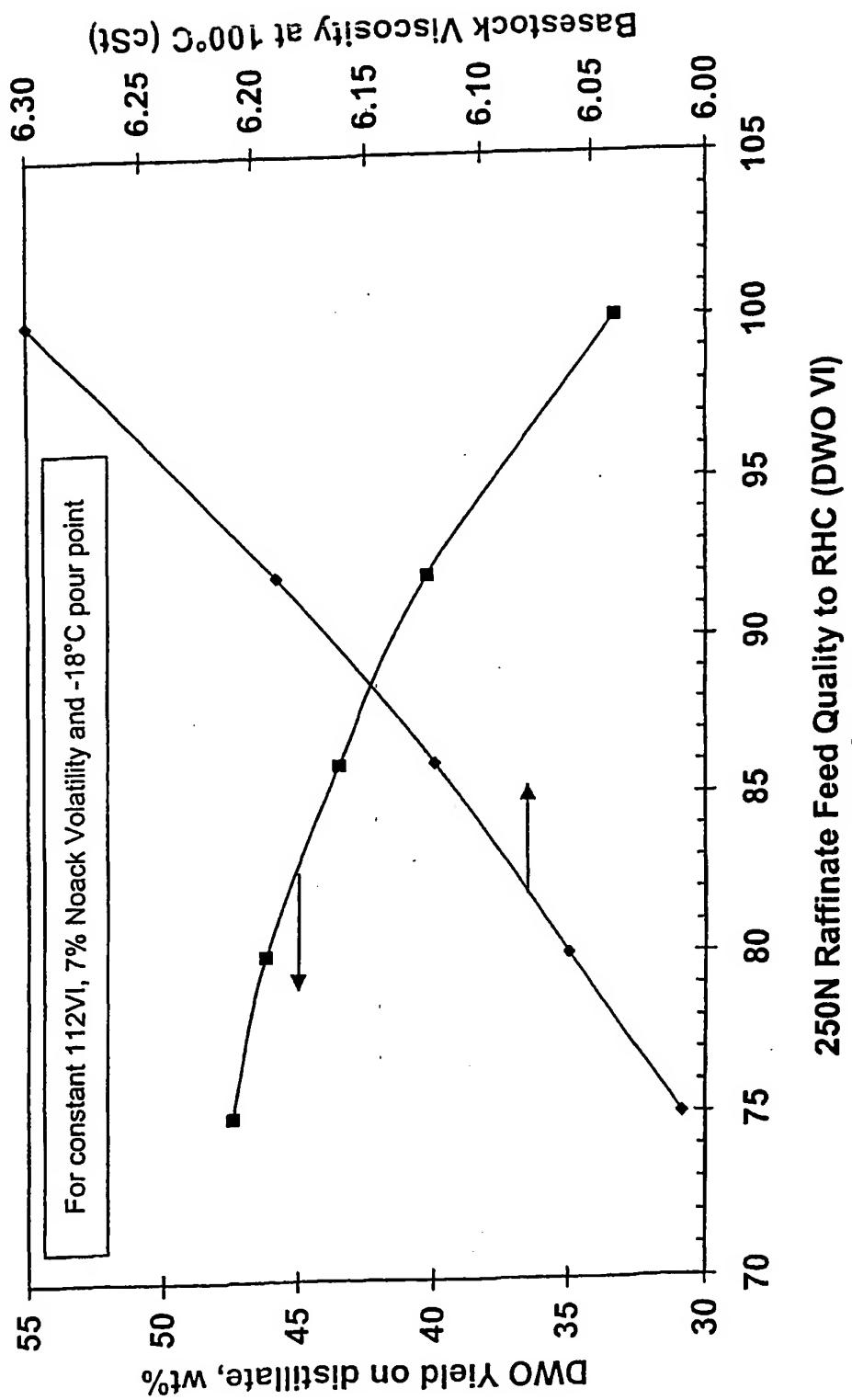


FIG. 3

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250N Raffinate Feed Quality to RHC (DWO VI)  
FIG. 4

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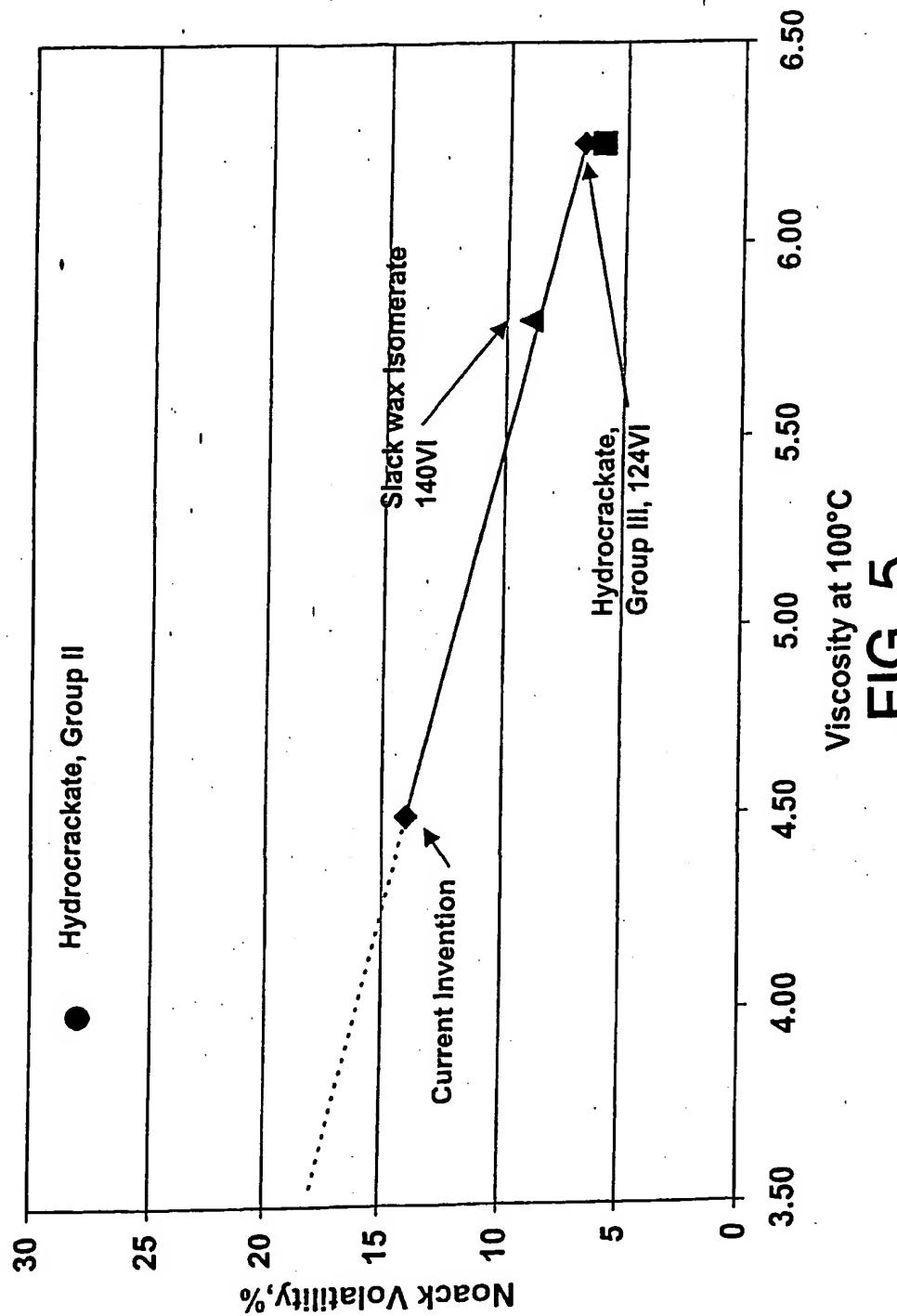
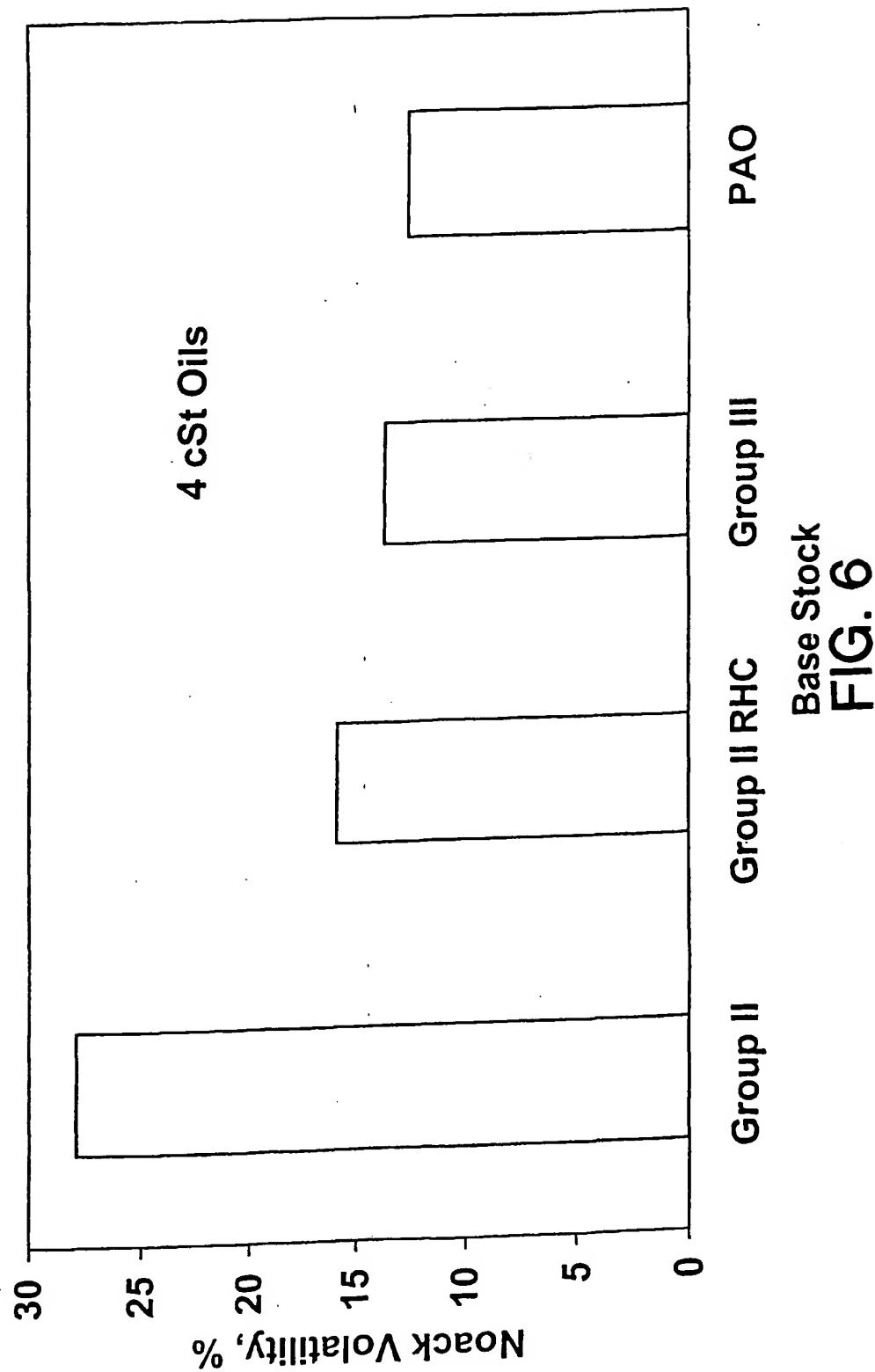


FIG. 5

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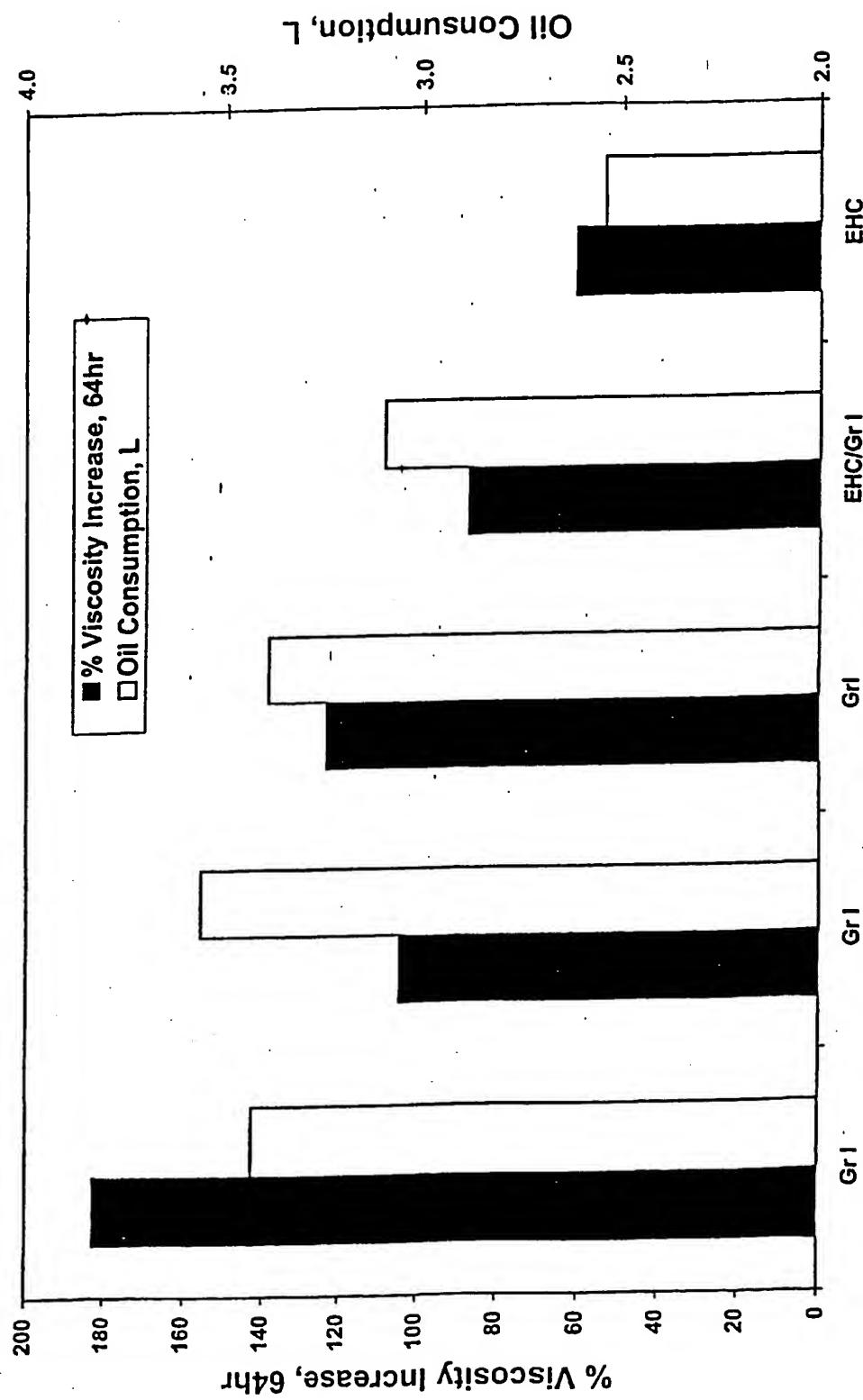


FIG. 7

**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US01/43530

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) : C10G 67/04, 73/08, 73/38  
US CL : 208/87, 57, 18, 27, 33

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
U.S. : 208/87, 57, 18, 27, 33

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
EAST search terms: hydroconversion, hydrofinishing, solvent extraction

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,935,416 A (CODY et al) 10 August 1999 (10.08.1999), see column 4, line 8 through column 8, line 28.	1-24
X	US 5,935,417 A (CODY et al) 10 August 1999 (10.08.1999), see column 2, line 25 through column 8, line 17.	1-24
X	US 5,911,874 A (CODY et al) 15 June 1999 (15.06.1999), see column 2, line 18 through column 6, line 28.	1-11,15,16
X	US 5,976,353 A (CODY et al) 02 November 1999 (02.11.1999), see column 2, line 10 through column 7, line 19.	1-11,15,16
X	US 6,096,189 A (CODY et al) 01 August 2000 (01.08.2000), see column 2, line 9 through column 6, line 58.	1-11,15-18
A	US 3,732,154 A (MILLS et al) 08 May 1973 (08.05.1973).	1-24
A	US 3,926,777 A (MENZL) 16 December 1975 (16.12.1975).	1-24
A	US 5,855,767 A (POWERS et al) 05 January 1999 (05.01.1999).	1-24
A	US 5,993,644 A (XIAO et al) 30 November 1999 (30.11.1999).	1-24



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

05 February 2002 (05.02.2002)

Date of mailing of the international search report

14 MAR 2002

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**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US01/43530

**C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT**

Category •	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,099,719 A (CODY et al) 08 August 2000 (08.08.2000).	1-24

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